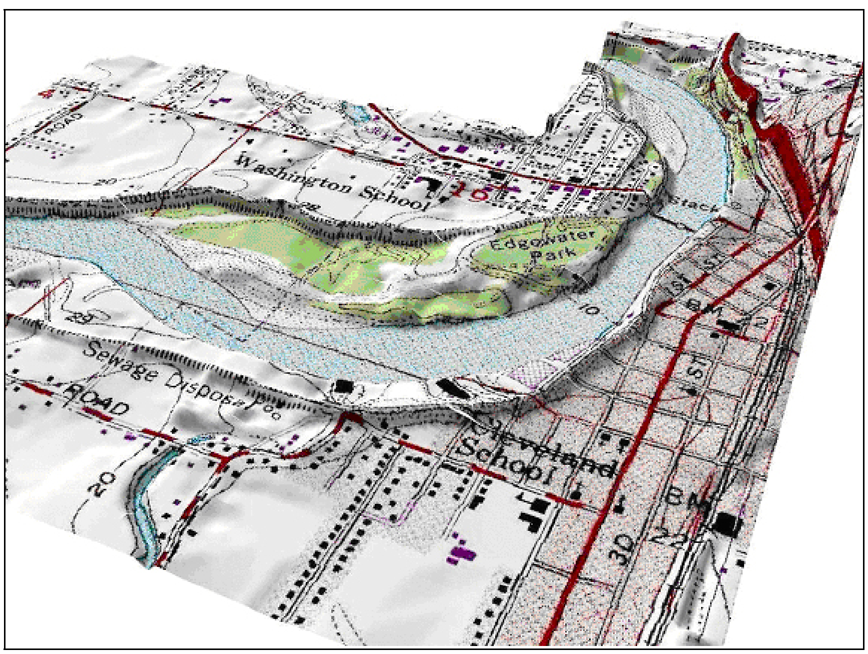
# PROTOCOL
# FOR
# MONITORING EFFECTIVENESS
# OF
# CHANNEL CONNECTIVITY, OFF CHANNEL HABITAT, AND WETLAND RESTORATION PROJECTS

# MC-6

**Washington Salmon Recovery Funding Board**

April 2004





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# TABLE OF CONTENTS

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# ORGANIZATION

This document details the monitoring design, procedures, and protocols necessary to document and report the effectiveness at the reach scale of projects restoring:

- **Channel Connectivity**
- **Off-Channel Habitat**
- **Wetlands**

This document is in compliance with the Washington Comprehensive Monitoring Strategy (Crawford et al. 2002).

Channel connectivity projects and off-channel habitat projects are designed to reconnect flood flow channels, oxbows, and other winter flood flow channels and winter rearing areas for fish and other aquatic organisms. Loss of channel connectivity is most often caused by manmade disturbances such as dikes, roads, fills, etc.

***The goal of channel connectivity projects is to restore lost channels and side channel rearing areas to active fish production and to dissipate the destructive effects of flood flows upon habitat.***

# MONITORING GOAL

***Determine whether projects that restore connectivity to channels that have previously been disconnected from the stream are effective at the reach scale in improving stream morphology and increasing fish abundance in the impacted area***.

This would include side channels, meander bends, old oxbows, and wetlands.

# QUESTIONS TO BE ANSWERED

Has the reconnected channel remained attached to the stream as designed?

Has off-channel stream morphology improved over time?

Has riparian vegetation in the off-channel impact area changed from upland to wetland species?

Has juvenile salmon abundance increased in the off-channel impact area over time?

# NULL HYPOTHESIS

Restoration of the disconnected channel to the stream has had no significant effect upon:

- Improving stream morphology and fish habitat as measured by residual pool volume and variation in depth within the connected channel.
- Improving the riparian plant community characteristics within the connected channel.
- Increasing juvenile abundance in the impacted area within the connected channel.

# OBJECTIVES

## BEFORE PROJECT OBJECTIVES (YEAR 0)

- Determine the overall size and configuration of the disconnected channel in the impact and control areas.
- Determine the plant community characteristics in the impact and control areas.
- Determine the overall stream morphology using Thalweg Profile in the impact and control areas.
- Determine the overall abundance of targeted juvenile salmon species in the impact and control areas.

## AFTER PROJECT OBJECTIVES (YEARS 1, 2, AND 5)

- Determine the effectiveness of the connected channel within the impacted area.
- Determine the plant community characteristics within the impact and control areas.
- Determine the overall stream morphology using Thalweg Profile in the impact and control areas.
- Determine the abundance of target juvenile salmon species within the control and impact areas.

# RESPONSE INDICATORS

**Level 1--Connected channel.** The channel connection must remain functional as designed for the project to be considered a success. The response indicator in this case is whether the channel has remained connected to the main channel of the stream thereby meeting design criteria. A reconnected channel is intact if there is present any visible flow through the channel during moderate flows.

**Channel connectivity indicator**

| Indicator Abbreviation | Description |
|---|---|
| CHANLCONN | Measure of whether the channel has remained connected to the stream, yes or no. |

**Level 2--Thalweg Profile.** The Thalweg profile characterizes pool-riffle relationships, sediment deposits, wetted width substrate characteristics, and channel unit-pool forming categories. Stream morphology sampling methods are taken from EMAP (Peck et al. Unpubl.), Section 7.4. Protocols summarizing EMAP Table 7-3 and 7-4 are found on page 17. Sampling is based upon establishing 11 regular transects within each identified stream reach. Pre-project measures of the variation of depth throughout the stream reach and the residual pool volume will be compared to detect post-project changes.

**Thalweg response indicators**

| Indicator Abbreviation | Description |
|---|---|
| AREASUM | Mean Thalweg vertical profile area for the study reach |
| RP100 | Mean Thalweg residual depth within the study reach |

**Level 2--Riparian species diversity and percent shading.** Using EMAP protocols, the percent shading (using a densitometer) and riparian species diversity are metrics that can be determined in a consistent manner. One would expect the percent shading and the species diversity to change over time after the channel has been reconnected.

**Riparian vegetation variables**

| Indicator Abbreviation | Description |
|---|---|
| XCDENBK | Mean percent shading at the bank (using a densitometer) |
| XPCMG | Proportion of the reach containing all 3 layers of riparian vegetation, canopy cover, under-story, and ground cover |

**Level 3--Numbers of juvenile salmon in the reach.** Abundance of salmon can be determined using juvenile counts. Juveniles will be monitored using protocols developed by Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife. Juvenile estimating procedures are found on pages 23 and 25. The least intrusive monitoring protocol should be used whenever possible. Impact areas will be compared to the controls and to controls and impacts on other streams as well. The metrics used will be numbers per square meter for juveniles.

**Fish abundance response variables**

| Indicator Abbreviation | Description |
|---|---|
| CHINJV | Measure of juvenile chinook 0 and yearling abundance within the study reach |
| COHOJV | Measure of coho yearling abundance within the study reach |
| SHPARR | Measure of steelhead yearling abundance within the study reach |

# MONITORING DESIGN

The Board will employ a Before and After Control Impact (BACI) experimental design to test for changes associated with restoring channel connectivity (Stewart-Oaten et al.1986). A BACI design samples the control and impact simultaneously at both locations at designated times before and after the impact has occurred. For this type of restoration, restoring channel connectivity would be the impact, that is, the location impacted by the restoration action, and a location upstream of the channel connectivity project would represent the control.

The BACI design tests for changes in stream morphology, riparian cover, and fish abundance at the channel connectivity project impact reach *relative to* the changes in stream morphology riparian cover and fish abundance observed at a control site upstream. This type of design is required when external factors (e.g., ocean conditions and harvesting) affect the population abundances at the control sites. The object is to see whether the difference between upstream (control) and downstream (impact) abundances, riparian cover, and stream morphology has changed as a result of the channel connectivity projects. The presence of multiple projects with control and impact locations will address the concerns detailed by Underwood (1994) regarding pseudoreplications. It is also not considered cost effective to employ multiple control locations for each passage project as recommended by Underwood. Although the ideal BACI would have multiple years of before data as well as after data, this was not possible with locally sponsored projects where there is a need and desire to complete their project as soon as possible.

The plan is to compare the most recent time period of sampling with Year 0 conditions, that is, before the projects. A paired *t*-test will be used to test for differences between control (upstream) and impact (downstream) sites during the most recent impact year and Year 0. In other words, we first compute the difference between the control and impact and use those values in a paired *t*-test. This test assumes that differences between the control and impact sites are only affected by the placing of instream structures and that external influences affect population abundance, riparian cover, and stream morphology in the same way at both the control and impact sites. The paired sample *t*-test does not have the same assumptions for normality and equality of variances of the two-sample *t*-test but only requires that the differences are approximately normally distributed. In fact, the paired-sample test is really equivalent to a one-sample *t*-test for a difference from a specified mean value.

To implement the design, we will monitor channel connectivity projects funded beginning with Round 4 in 2004. This will ultimately provide 10 total projects to test for effectiveness. The number of projects proposed for funding in each category will be based upon the calculated sample size needed to obtain statistically significant information in the shortest amount of time. If there are insufficient projects funded in any one year to obtain a proper sample size, then the design will be used in multiple years until the critical sample size is reached.

The variance associated with impact and control areas will not be known until sampling has occurred in Year 0 of both impact and control areas. After Year 0, a better estimate of the true sample size needed to detect change will be available. Cost estimates and sampling replicates may need to be adjusted at that time.

At the end of the effectiveness monitoring testing, there will be one year of “Before” impact information for all projects for both control and impact areas, and three years of “After” impact information for the same control and impact areas for each of the projects.

Depending upon circumstances, the results may also be tested for significance using a linear regression model of the data points for each of the years sampled and for each of the indicators tested.

Testing for significant trends can begin as early as Year 1. Final sampling may be completed in 2009.

# DECISION CRITERIA

Table 1 details the decision criteria used in evaluating whether there has been a statistically significant change in the response indicators when testing the null hypothesis.

**Table 1. Decision criteria and statistical test type**

| Habitat | Indicators | Metric | Test Type | Decision Criteria |
|---|---|---|---|---|
| Level 1 Channel Modification | Measure of whether the channel has remained connected to the stream per design (CHANLCONN) | Yes/No | None. Count of functional channel reconnections | ≥ 80% of projects are intact by Year 5. Intact if there is present any visible flow through the channel during moderate flows. |
| Level 2 Stream Morphology | Mean residual pool vertical profile area (AREASUM) | $m^2$ | Linear Regression or Paired *t*-test | Alpha =0.10 for one-sided test. Detect a minimum 20% change between Treatment and control by Year 5 |

| Habitat | Indicators | Metric | Test Type | Decision Criteria |
|---|---|---|---|---|
| | Mean residual depth. (RP100) | cm | Linear Regression or Paired *t*-test | Alpha =0.10 for one-sided test. Detect a minimum 20% change between Treatment and control by Year 5 |
| Level 2 Riparian Habitat | Mean percent shading at the bank (using a densitometer) (XCDENBK) | % | BACI Paired *t*-test | Alpha =0.10 for one-sided test. Detect a minimum 20% change between Treatment and control by Year 5 |
| | Proportion of the reach containing all 3 layers of riparian vegetation, canopy cover, under-story, and ground cover (XPCMG) | % | BACI Paired *t*-test | Alpha =0.10 for one-sided test. Detect a minimum 20% change between Treatment and control by Year 5 |
| Level 3 Juvenile Fish Abundance | Chinook juvenile abundance (CHINJUV) | #/m2 | BACI Paired *t*-test | Alpha =0.10 for one-sided test. Detect a minimum 20% change between Treatment and control by Year 5 |
| | Coho juvenile abundance (COHOJUV) | #/m2 | BACI Paired *t*-test | Alpha =0.10 for one-sided test. Detect a minimum 20% change between Treatment and control by Year 5 |
| | Steelhead juvenile abundance (SHJUV) | #/m2 | BACI Paired *t*-test | Alpha =0.10 for one-sided test. Detect a minimum 20% change between Treatment and control by Year 5 |

# SAMPLING

## SELECTING SAMPLING REACHES

### *IMPACT AREAS*

Disconnected areas are often not very large and may be measured in their entirety, or may require only one stream reach identified and laid out according to the methods on page 12. In keeping with EMAP protocols, detailed written description of the sample reach should be recorded.

### *CONTROL AREA*

A control reach located upstream of the project site should be selected and designed in the same manner as the impact reach. It should be a stable portion of the main channel and does not need to contain off-channel areas similar to the area impacted. This is true because we are measuring change in the connected channel against the main channel characteristics. By moving water into a reconnected channel we would expect changes to the main channel in the area impacted by the side channel. Therefore a stable upstream control is needed.

## BEFORE PROJECT SAMPLING

All channel connectivity projects identified for long-term monitoring by the SRFB must have completed pre-project Year 0 monitoring before beginning the project.

Year 0 monitoring will consist of:

- Determining the linear distance in kilometers to the nearest tenth and acreage of area to be reconnected.
- Determining if and to what extent the area is inundated during winter flow periods.
- Determining the riparian cover composition in the side channel
- Determining side channel morphology and characteristics within the project area using Thalweg Profile.
- Determining the abundance of juvenile salmon during summer low flow and winter high flows.

## AFTER PROJECT SAMPLING

Upon completion of the project, Years 1, 2, and 5 monitoring will consist of:

- Confirming the channel has remained connected to the mainstream.
- Determining if and to what extent the area is inundated during winter flow periods.
- Determining the riparian cover composition in the side channel.
- Measuring side channel morphology and structure using Thalweg Profile.
- Determining abundance of juvenile salmon in the impact and control areas during summer low flow or winter high flows based on project objectives.

# METHOD FOR LAYING OUT CONTROL AND IMPACT STREAM REACHES FOR WADEABLE STREAMS

**Protocol taken from:** ***Peck et al. (Unpubl.), pp. 63-65, Table 4-4; Mebane et al. (2003)***

## EQUIPMENT

Metric tape measure, surveyor stadia rod, handheld GPS device, 3 - 2 ft. pieces of rebar painted bright orange, engineer flagging tape, waterproof markers

## SAMPLING CONCEPT

The concept of EMAP sampling is that randomly selected reaches located on a stream can be used to measure changes in the status and trends of habitat, water quality, and biota over time if taken in a scientifically rigorous manner per specific protocols. We have applied the EMAP field sampling protocols for measuring effectiveness of restoration and acquisition projects. Instead of a randomly selected stream reach, the stream reach impacted by the project is sampled. These “impact” areas have been matched with “control” areas of the same length and size on the same stream whenever possible.

Within each sampled project reach a series of transects A-K are taken across the stream and riparian zone as points of reference for measuring characteristics of the stream and riparian areas. The transects are then averaged to obtain an average representation of the stream reach.

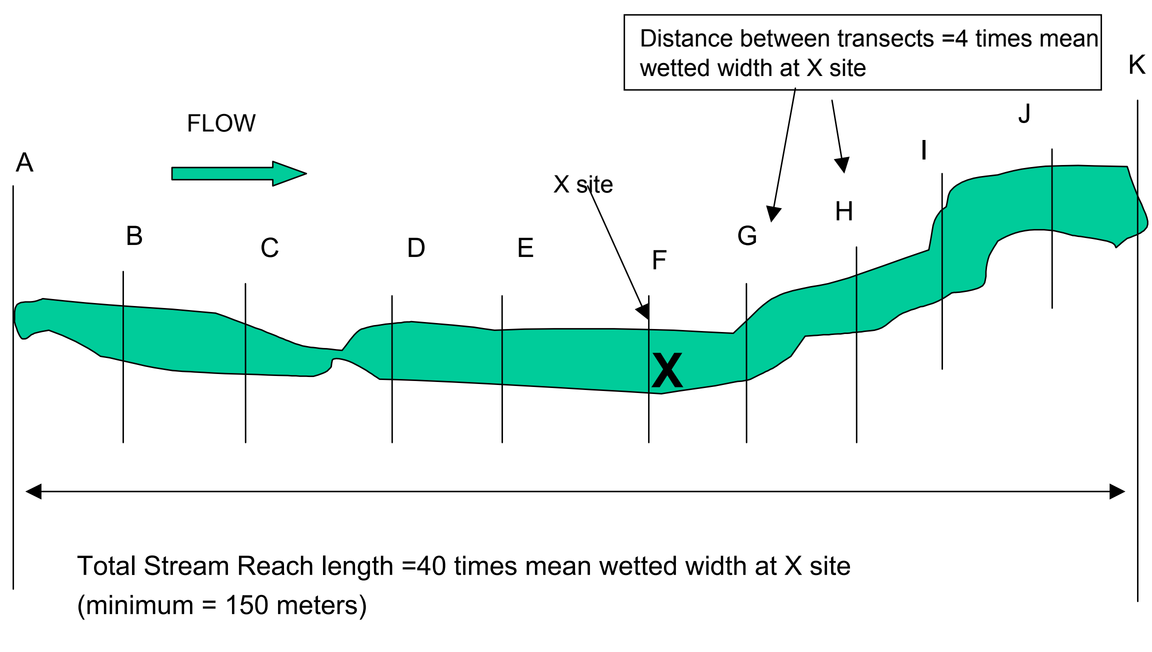


**Figure 1. Sampled project reach**

# LAYING OUT THE TREATMENT AND CONTROL STREAM REACHES

**Step 1**: Using a handheld GPS device, determine the location of the **X sites** and record latitude and longitude of same on waterproof sheets. The X sites should be considered the center of the Impact and Control study reach. The Impact reach X site must fall within the project affected area. The location of the control X site should be determined based upon the project category and associated procedure (MC-1 to MC-10). Mark the X site on the bank above the high water mark with one of the rebar stakes so that the X site can be found in future years. Use a surveyor's rod or tape measure to determine the wetted width of the channel at five places considered to be of "typical" width within approximately five channel widths upstream and downstream of the X site sample reach location. For streams less than 4 m in width the reach should be at minimum 150 m.

**Step 2**: Check the condition of the stream upstream and downstream of the X site by having one team member go upstream and one downstream. Each person proceeds until they can see the stream to a distance of 20 times the stream width (equal to one half the sampling reach length) determined in Step 1.

*For example if the reach length is determined to be 150 m, each person would proceed 75 m from the X site to lay out the reach boundaries.*

**NOTE:** *For restoration projects less than 40 stream widths, the entire project's length should be sampled and a control area of similar size should likewise be developed within the treatment stream either upstream or downstream as appropriate.*

**Step 3**: Determine if the reach needs to be adjusted around the X site due to confluences with lower order streams, lakes, reservoirs, waterfalls, or ponds. Also adjust the boundaries to end and begin with the beginning of a pool or riffle, but not in the center of the pool or riffle. Hankins and Reeves (1988) have shown that measures of the variance of juvenile fish populations is decreased by using whole pool/riffles in the sample area.

**Step 4:** Starting back at the X site, measure a distance of **20 channel widths** down one side of the stream using a tape measure. Be careful not to cut corners. Enter the channel to make measurements only when necessary to avoid disturbing the stream channel prior to sampling activities. This endpoint is the downstream end of the reach and is flagged as transect "A".

**Step 5**: Using the tape, measure 1/10$^{th}$ (4 channel widths in big streams or 15 m in small streams) of the required stream length upstream from the start point (transect A). Flag this spot as the next cross section or transect (transect B).

**Step 6**: Proceed upstream with the tape measure and flag the positions of nine additional transects (labeled "C" through "K" as you move upstream) at intervals equal to 1/10$^{th}$ of the reach length.

# METHOD FOR CHARACTERIZING RIPARIAN VEGETATION STRUCTURE

**Protocol taken from:** ***Peck et al. (Unpubl.), Table 7-10; Kauffman et al. (1999)***

## PURPOSE

This protocol is designed to determine the changes in riparian vegetation due to a restoration or acquisition project where riparian vegetation has either been planted or has been protected.

## EQUIPMENT

Convex spherical densitometer, field waterproof forms.

## SITE SELECTION

The sample reaches are laid out according to page 12.

## SAMPLING DURATION

Sampling should occur during July-August when vegetation is at its maximum growth.

## PROCEDURES FOR MEASURING RIPARIAN VEGETATION AND STRUCTURE

Following are taken from Table 7-10 of EMAP protocols

1. Standing in mid-channel at a cross-section transect (A-K), estimate a 5m distance upstream and downstream (10m length total).
2. Facing the left bank (left as you face downstream), estimate a distance of 10m back into the riparian vegetation or until an exclosure is encountered. On steeply sloping channel margins, estimate the distance into the riparian zone as if it were projected down from an aerial view.
3. Within this 10 m X 10 m area, conceptually divide the riparian vegetation into three layers: a canopy layer (>5 m [16ft] high), an understory (0.5 to 5 m [20 inches to 16ft.] high), and a ground cover layer (<0.5 m high).
4. Within this 10 m X 10 m area, determine the dominant vegetation type for the canopy layer as either **Deciduous, Coniferous, broadleaf Evergreen, Mixed, or None.** Consider the layer mixed if more than 10% of the areal coverage is made up of the alternate vegetation type. Indicate the appropriate vegetation type in the "Visual Riparian Estimates" section of the Channel/Riparian Cross Section Form.
5. Determine separately the areal cover class of large trees (>0.3 m [1ft] diameter breast height [DBH]) and small trees (<0.3m DBH) within the canopy layer. Estimate areal cover as the amount of shadow that would be cast by a particular layer alone if the sun were directly overhead. Record the appropriate cover class on the field data form (**"0"= absent: zero cover, "1"= sparse: <10%, "2"= moderate: 10-40%, "3"=heavy: 40-75%, or "4"= very heavy: >75%)**.
6. Look at the understory layer. Determine the dominant vegetation type for the understory layer as described in Step 4.
7. Determine the areal cover class for woody shrubs and saplings separately from non-woody vegetation within the understory, as described.
8. Look at the ground cover layer. Determine the areal cover class for woody shrubs and seedlings, non-woody vegetation, and the amount of bare ground present as described in Step 5 for large canopy trees.
9. Repeat steps 1 through 8 for the right bank.
10. Repeat steps 1 through 9 for all cross-section transects, using a separate field data form for each transect.

**Table 2. Field data form for recording visual riparian estimates. One form for each transect A-K**

| Riparian Vegetation Cover | Left Bank | | | | | Right bank | | | | | Flag |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Canopy (> 5m high)** | | | | | | | | | | |
| Vegetation type | **D** | **C** | **E** | **M** | **N** | **D** | **C** | **E** | **M** | **N** | |
| Big trees (trunk > 0.3m DBH) XCL | **0** | **1** | **2** | **3** | **4** | **0** | **1** | **2** | **3** | **4** | |
| Small trees (trunk ,0.3m DBH) XCS | **0** | **1** | **2** | **3** | **4** | **0** | **1** | **2** | **3** | **4** | |
| | **Understory (0.5 to 5m high)** | | | | | | | | | | |
| Vegetation type | **D** | **C** | **E** | **M** | **N** | **D** | **C** | **E** | **M** | **N** | |
| Woody shrubs and saplings XMW | **0** | **1** | **2** | **3** | **4** | **0** | **1** | **2** | **3** | **4** | |
| Non-woody herbs grasses and forbs XMH | **0** | **1** | **2** | **3** | **4** | **0** | **1** | **2** | **3** | **4** | |
| | **Ground cover (,0.5m high)** | | | | | | | | | | |
| Woody shrubs & saplings XGW | **0** | **1** | **2** | **3** | **4** | **0** | **1** | **2** | **3** | **4** | |
| Non-woody herbs grasses and forbs XGH | **0** | **1** | **2** | **3** | **4** | **0** | **1** | **2** | **3** | **4** | |
| Barren dirt or duff XGB | **0** | **1** | **2** | **3** | **4** | **0** | **1** | **2** | **3** | **4** | |

**Table 3. taken from Kauffman et al. (1999) details the parameter codes and precision metrics of EMAP procedures conducted in Oregon.** Parameters in bold type are the most precise. This table is provided for information purposes only.

| Code | Variable name and description | RMSE = $\sigma_{rep}$ | CV = $\sigma_{rep}$ / ”(%) | S/N = $\sigma^2_{st(yr)}$ / $\sigma^2_{rep}$ |
|---|---|---|---|---|
| XCL | Large diameter tree canopy cover (proportion of riparian) | 0.057 | 38 | 4.6 |
| XCS | Small diameter tree canopy cover (proportion of riparian) | 0.12 | 55 | 1.4 |
| **XC** | **Tree canopy cover (proportion of riparian)** | **0.12** | **33** | **2.4** |
| **XPCAN** | **Tree canopy presence (proportion of riparian)** | **0.08** | **8.7** | **10** |
| XMW | Mid-layer woody vegetation cover (proportion of riparian) | 0.12 | 41 | 0.9 |
| XMH | Mid-layer herbaceous vegetation cover (proportion of riparian) | 0.13 | 100 | 0.9 |
| **XM** | **Mid-layer vegetation cover (proportion of riparian)** | **0.19** | **44** | **0.6** |
| **XPMID** | **Mid-layer vegetation presence (proportion of riparian)** | **0.03** | **3.5** | **2.1** |
| XGW | Ground layer woody vegetation cover (proportion of riparian) | 0.17 | 77 | 0.1 |
| XGH | Ground layer herbaceous vegetation cover (proportion of riparian) | 0.16 | 40 | 1.1 |
| XGB | Ground layer barren or duff cover (proportion of riparian) | 0.07 | 47 | 2.0 |

| | | | | |
|---|---|---|---|---|
| XG | Ground layer vegetation cover (proportion of riparian) | 0.22 | 36 | 0 |
| PCAN_C | Conifer riparian canopy (proportion of riparian) | 0.11 | 58 | 8.5 |
| PCAN_D | Broadleaf deciduous riparian canopy (proportion of riparian) | 0.13 | 31 | 7.4 |
| PCAN_M | Mixed conifer-broadleaf canopy (proportion of riparian) | 0.16 | 65 | 2.9 |
| PMID_C | Conifer riparian mid-layer (proportion of riparian) | 0.02 | 55 | 37 |
| PMID_D | Broadleaf deciduous riparian mid-layer (proportion of riparian) | 0.33 | 58 | 0.7 |
| PMID_M | Mixed conifer-broadleaf canopy (proportion of riparian) | 0.32 | 87 | 0.6 |

## PROCEDURES FOR MEASURING CANOPY COVER

Canopy cover is determined for the stream reach in the treatment and control areas at each of the 11 cross section transects. A convex spherical densitometer (Model B) is used. Six measurements are obtained at each cross section transect at mid-channel

1. At each cross-section transect, stand in the stream at mid-channel and face upstream.
2. Hold the densitometer 0.3 m (1 ft.) above the stream. Hold the densitometer level using the bubble level. Move the densitometer in front of you so that your face is just below the apex of the taped “V”.
3. Count the number of grid intersection points within the “V” that are covered by either a tree, a leaf, or a high branch. Record the value (0-17) in the CENUP field of the canopy cover measurement section of the form.
4. Face toward the left bank (left as you face downstream). Repeat steps 2 and 3, recording the value in CENL field of the data form.
5. Repeat steps 2 and 3 facing downstream, and again while facing the right bank (right as you look downstream). Record the values in the CENDWN and CENR fields of the field data form.
6. Repeat steps 2 and 3 again, this time facing the bank while standing first at the left bank, then the right bank. Record the value in the LFT and RGT fields of the data form.
7. Repeat steps 1-6 for each cross-section transect (A-K). Record data for each transect on a separate data form.
8. If for some reason a measure cannot be taken, indicate in the “Flag” column.

| Location | 1-17 | Flag |
|---|---|---|
| CENUP | | |
| CENL | | |
| CENDWN | | |
| CENR | | |
| LFT | | |
| RGT | | |

**Figure 2. Canopy Density form**

Each of the measures taken at the center of the stream are summed for all 11 transects and converted to a percentage based upon a maximum score of 17 per transect. The results are then averaged to produce a mean % canopy density at mid-stream (XCDENMID).

Each of the measures taken at the banks of the stream are summed for all 11 transects and converted to a percentage based upon a maximum score of 17 per transect. The results are then averaged to produce a mean % canopy density at the stream bank (XCDENBK).

**Each of the measures are totaled and averaged to produce the following table of riparian vegetative cover.** This table is provided for information purposes only.

**Table 4. Comparison of precision for indicators.** The shaded composite variables are considered the most important in terms of their precision and are the ones that will be used to determine effectiveness of riparian plantings. RMSE = $\sigma_{rep}$ is the root mean square error. The lower the value, the more precise the measurement. CV $\sigma_{rep}$ / ”(%) is the coefficient of variation. The lower the number, the more precise the measurement. S/N = $\sigma^2_{st(yr)} / \sigma^2_{rep}$ is the signal to noise ratio. The higher the number, the more that metric is able to discern trends or changes in habitat in a single or multiple sites.

| Variable | Description | RMSE = $\sigma_{rep}$ | CV = $\sigma_{rep}$ / ”(%) | S/N = $\sigma^2_{st(yr)} / \sigma^2_{rep}$ |
|---|---|---|---|---|
| XCDENBK | Mean % canopy density at bank (Densitometer reading) | 3.9 | 4.4 | 17 |
| **XC DENMID** | **Mean % canopy density mid-stream (Densitometer reading)** | **5.8** | **8.1** | **15** |
| XCM | Mean riparian canopy + mean mid-layer cover | 0.22 | 33 | 1.4 |
| XPCM | Riparian canopy and mid-layer presence (proportion of reach) | 0.08 | 9.8 | 7.9 |
| **XPCMG** | **3-layer riparian vegetation presence (proportion of reach)** | **0.08** | **9.8** | **8.0** |

# METHOD FOR CHARACTERIZING STREAM MORPHOLOGY, THALWEG PROFILE

**Protocol taken from*: Peck et al. (Unpubl.), Table 7-3; Kauffman et al. (1999)***

## PURPOSE

The Thalweg profile can detect changes in the stream morphology associated with habitat restoration projects designed to improve pool-riffle relationships, provide velocity changes and other structure beneficial as hiding and holding habitat for salmonids.

## EQUIPMENT

Surveyor's telescoping rod, 50 m measuring tape, laser range finder, camera tripod, 2 - ½ in. diameter PVC pipe, 2-3 m long, meter stick, surveyor tape, Bearing compass, fisherman's vest with lots of pockets, chest waders, appropriate waterproof forms.

## SITE SELECTION

The sample reaches are those laid out on page 12.

## SAMPLING DURATION

Sampling should occur during August-September.

## PROCEDURE

The Thalweg Profile is a longitudinal survey of depth, habitat class, presence of soft/small sediment deposits, and off-channel habitat at 100 equally spaced intervals (150 in streams less than 2.5 m wide) along the centerline between the two ends of the sampling reach. "Thalweg" refers to the flow path of the deepest water in a stream channel. Wetted width is measured and substrate size is evaluated at 21 equally spaced cross-sections (at 11 regular Transects A through K plus 10 supplemental cross-sections spaced mid-way between each of these).

**Step 1**: Determine the interval between measurement stations based on the wetted width used to determine the length of the sampling reach. For widths < 2.5 m, establish stations every 1 m. For widths between 2.5 and 3.5 m, establish stations every 1.5 m. For widths > 3.5 m, establish stations at increments equal to 0.01 times the sampling reach length.

**Step 2**: Complete the header information on the Thalweg Profile and Woody Debris Form, noting the transect pair (downstream to upstream). Record the interval distance determined in Step 1 in the "INCREMENT" field on the field data form.

**NOTE:** *If a side channel is present and contains between 16 and 49% of the total flow, establish secondary cross-section transects as necessary. Use separate field data forms to record data for the side channel, designating each secondary transect by checking both "X" and the associated primary transect letter (e.g., XA, XB, etc.). Collect all channel and riparian cross-section measurements from the side channel.*

**Table 5. Codes for recording pool and channel conditions**

| POOL FORMING CODES | | CHANNEL UNIT CODES | |
|---|---|---|---|
| N | Not a pool | PP | Pool, Plunge |
| W | Large Woody Debris | PT | Pool, Trench |
| R | Rootwad | PL | Pool, Lateral Scour |
| B | Boulder or Bedrock | PB | Pool, Backwater |
| F | Unknown, Fluvial | PD | Pool, Impoundment |
| | | GL | Glide |
| | Combinations eg. WR, BR, WRB | RI | Riffle |
| | | RA | Rapid |
| | | CA | Cascade |
| | | FA | Falls |
| | | DR | Dry Channel |

**Step 3**: Begin at the downstream end (station "0") of the first transect (Transect "A").

**Step 4**: Measure the wetted width if you are at station "0", station "5" (if the stream width defining the reach length is 2.5 m), or station "7" (if the stream width defining the reach length is < 2.5 m). Wetted width is measured across and over mid-channel bars and boulders. Record the width on the field data form to the nearest 0.1 m for widths up to about 3 meters, and to the nearest 5% for widths > 3 m. This is 0.2 m for widths of 4 to 6 m, 0.3 m for widths of 7 to 8 m, and 0.5 m for widths of 9 or 10 m, and so on. For dry and intermittent streams, where no water is in the channel, record zero for wetted width.

**NOTE:** *If a mid-channel bar is present at a station where wetted width is measured, measure the bar width and record it on the field data form.*

**Step 5**: At station "5" or "7" (see above) classify the substrate particle size at the tip of your depth measuring rod at the left wetted margin and at positions 25%, 50%, 75%, and 100% of the distance across the wetted width of the stream. This procedure is identical to the substrate size evaluation procedure described for regular channel cross-sections A through K, except that for these mid-way supplemental cross-sections, substrate size is entered on the Thalweg Profile side of the field form.

**Step 6**: At each Thalweg Profile station, use a meter ruler or a calibrated pole or rod to locate the deepest point (the "thalweg"), which may not always be located at mid-channel. Measure the thalweg depth to the nearest cm, and record it on the Thalweg Profile form. Read the depth on the side of the ruler, rod, or pole to avoid inaccuracies due to the wave formed by the rod in moving water.

**NOTE**: For dry and intermittent streams where no water is in the channel, record zeros for depth.

**NOTE:** At stations where the thalweg is too deep to measure directly, stand in shallower water and extend the surveyor's rod, calibrated rod, or pole at an angle to reach the thalweg. Determine the rod angle by resting the laser range finder on the upper surface of the rod and reading the angle on the external scale of the laser range finder. Leave the depth reading for the station blank, and record a "U" flag. Record the water level on the rod and the rod angle in the comments section of the field data form. For even deeper depths, it is possible to use the same procedure with a taut string as the measuring device. Tie a weight to one end of a length of string or fishing line and then toss the weight into the deepest channel location. Draw the string up tight and measure the length of the line that is under water. Measure the string angle with the laser range finder exactly as done for the surveyor's rod.

**Step 7**: At the point where the thalweg depth is determined, observe whether unconsolidated, loose ("soft") deposits of small diameter (<16mm), sediments are present directly beneath your ruler, rod, or pole. Soft/small sediments are defined here as fine gravel, sand, silt, clay or muck readily apparent by "feeling" the bottom with the staff. Record presence or absence in the "SOFT/SMALL SEDIMENT" field on the field data form. Note: A thin coating of fine sediment or silty algae coating the surface of cobbles should not be considered soft/small sediment for this assessment. However, fine sediment coatings should be identified in the comments section of the field form when determining substrate size and type.

**Step 8**: Determine the channel unit code and pool forming element codes for the station. Record these on the field data form using the standard codes provided. For dry and intermittent streams where no water is in the channel, record habitat type as dry channel (DR).

**Step 9**: If the station cross-section intersects a mid-channel bar, indicate the presence of the bar in the "BAR WIDTH" field on the field data form.

**Step 10**: Record the presence or absence of a side channel at the station's cross-section in the "SIDE CHANNEL" field on the field data form

**Step 11**: Record the presence or absence of quiescent off-channel aquatic habitats, including sloughs, alcoves and backwater pools in the "BACKWATER" column of the field form.

**Step 12**: Proceed upstream to the next station and repeat Steps 4 through 11.

**Step 13**: Repeat Steps 4 through 12 until you reach the next transect. At this point, complete Channel/Riparian measurements at the new transect (Section 7.5). Then prepare a new Thalweg Profile and Woody Debris Form and repeat Steps 2 through 12 for each of the reach segments, until you reach the upstream end of the sampling reach (Transect "K").

| THALWEG PROFILE FORM | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| SITE NAME: | | | | | | DATE: | | VISIT: 1 2 | | |
| SITE ID: | | | | | | TEAM ID: | | | | |
| TRANSECT (X) A-B B-C C-D D-E E-F F-G G-H H-I I-J J-K | | | | | | | | | | |
| THALWEG PROFILE | | | | | | | Increment (m) → | | | |
| Station | Thalweg Depth cm (XXX) | Wetted Width (XX.X) | bar Width Y/N | bar Width (XX .X) | Soft/Small sediment (X for yes) | Channel Unit Code | Pool Form Code | Side Channel (X for yes) | Flag | Comments |
| 0 | | | | | | | | | | |
| 1 | | | | | | | | | | |
| 2 | | | | | | | | | | |
| 3 | | | | | | | | | | |
| 4 | | | | | | | | | | |
| 5 | | | | | | | | | | |
| 6 | | | | | | | | | | |
| 7 | | | | | | | | | | |
| 8 | | | | | | | | | | |
| 9 | | | | | | | | | | |
| 10 | | | | | | | | | | |
| 11 | | | | | | | | | | |
| 12 | | | | | | | | | | |
| 13 | | | | | | | | | | |
| 14 | | | | | | | | | | |
| TOTAL | | | | | | | | | | |
| MEAN | | | | | | | | | | |
| VAR | | | | | | | | | | |
| SE | | | | | | | | | | |

**Figure 3. Thalweg Profile form**

# METHOD FOR MEASURING RESIDUAL DEPTH

**Protocol taken from:** ***Peck et al. (Unpubl.), Table 7-6; Kauffman et al. (1999)***

## PURPOSE

Using the following methods, the water surface slope and bearing can be determined. These measures can be used to calculate residual pool depth. Residual pool volume is the amount of water that would remain in the pools if there were not flow and the pools were impermeable basins. The intent of measuring this parameter is to show the changes in cross sectional stream complexity typified by pools and riffles.

Slope and bearing are measured using two people by back-sighting downstream between transects.

## EQUIPMENT

Surveyor's telescoping stadia rod, 50 m measuring tape, laser range finder, camera tripod, 2 – ½ in diameter PVC pipe, 2-3 m long, surveyor flagging tape, Bearing compass, fisherman's vest with lots of pockets, chest waders, appropriate waterproof forms.

## PROCEDURE

**Step 1**: Stand in the center of the channel at the downstream cross-section transect. Determine if you can see the center of the channel at the next cross-section transect upstream without sighting across land, (i.e. do not short circuit a meander bend). If not you will have to take supplementary slope and bearing measurements.

**Step 2**: Set up a tripod in shallow water or have one person hold a **stadia rod** at the downstream cross-section transect (or at a supplemental point). Standing tall in a position with your feet as near as possible to the water surface elevation, set the **tripod** extension and mark it with a piece of **flagging tape** at your eye level. Remember the depth of water in which you are standing when you adjust the flagging to eye level.

**Step 3**: Walk upstream to the next cross-section transect. Find a place to stand at the upstream transect that is at the same depth as where you stood at the downstream transect when you set up the eye level flagging.

**Step 4**: With the **laser range finder**, site back downstream on your flagging at the downstream transect. Read and record the percent slope in the "MAIN" section on the **Slope and Bearing Form**. Record the "PROPORTION" as 100%.

**Step 5**: Stand in the middle of the channel at upstream transect, and site back with your **compass** to the middle of the channel at the downstream transect. Record the bearing (degrees) in the "MAIN" section of the Slope and Bearing Form.

**Step 6**: Retrieve the tripod from the downstream cross-section station and setup at the next upstream transect as described in Step 2.

**Step 7**: When you get to each new cross-section transect, back sight on the previous transect. Repeat steps 2 through 6 above.

## Residual Pools

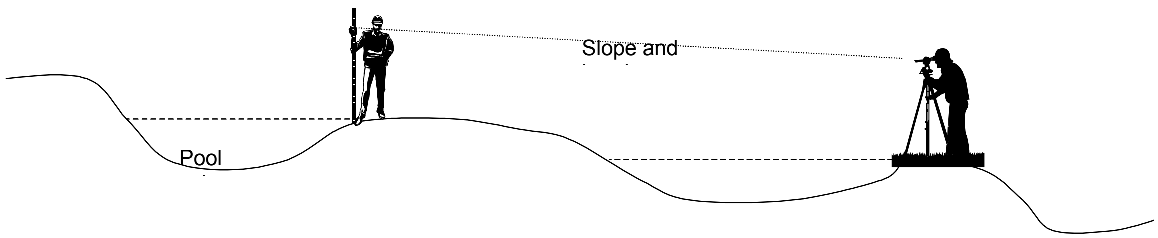


**Figure 4. Residual Pools**

| Project No: | | Con/Impact | | Sample Year | | | Date: | | Stream | |
|---|---|---|---|---|---|---|---|---|---|---|
| TRANSECT | MAIN | | | $1^{ST}$ SUPPLEMENTAL | | | $2^{ND}$ SUPPLEMENTAL | | | FLAG |
| | SLOPE XX.X % | BEARING 0-359 | BEARING 0-359 | SLOPE XX.X % | BEARING 0-359 | BEARING 0-359 | SLOPE XX.X % | BEARING 0-359 | BEARING 0-359 | |
| A > B | | | | | | | | | | |
| B > C | | | | | | | | | | |
| C > D | | | | | | | | | | |
| D > E | | | | | | | | | | |
| E > F | | | | | | | | | | |
| F > G | | | | | | | | | | |
| G > H | | | | | | | | | | |
| H > I | | | | | | | | | | |
| I > J | | | | | | | | | | |
| J > K | | | | | | | | | | |

| FLAG | COMMENTS |
|---|---|
| | |
| | |
| | |

**Figure 5. Form for recording residual pool bearings**

# METHOD FOR ESTIMATING INSTREAM JUVENILE SALMONID ABUNDANCE USING ELECTROFISHING

**Protocol taken from:** ***Zippin (1956); Hankins (1984); Hankins and Reeves (1988)***

## PURPOSE

Estimating the density of juvenile salmonids at the project allows the investigator to obtain a sample over time of the change in abundance of rearing juvenile salmonids produced in the stream reach examined. Instead of a randomly selected stream reach, the stream reach impacted by the project is sampled. These “impact” areas have been matched with “control” areas of the same length and size on the same stream whenever possible in order to produce a BACI experimental design.

## EQUIPMENT

Use a backpack electrofisher consisting of an anode and cathode pole and capable of producing adjustable pulsed D.C. voltage up to 300 volts and an amp meter allowing adjustable amperage up to 1.5 amps. Determine that all team members are wearing waders and gloves, polarized sunglasses, and capture nets. The electrofisher should have automatic current switches in case the operator falls. The electrofisher should be equipped with an audio indicator when the unit is turned on and warning devices when voltage or current exceeds 300 volts or 1.5 amps. Appropriate capture nets and buckets should be available to capture and hold fish.

## SITE SELECTION

The sample reaches are those laid out on page 12.

Be sure that all collectors’ permits and ESA clearances have been obtained before proceeding with electrofishing.

## SAMPLING DURATION

Sampling for juvenile abundance should occur during the low flow period in late summer. It should be done in one or two days within the same week to avoid changes in conditions, rainfall events, etc.

## SAMPLING PROCEDURE

The removal method is based upon the theory that a segment of stream can be fished two or more times to attempt to remove all of the fish and obtain a total count. Because some fish are successful in avoiding capture, a total count cannot normally be obtained. However, a regression equation can be developed that will estimate, with known accuracy and precision, the total number of fish in the sampled reach. The sample team will place blocking nets at the upstream and downstream end of the sample reach in order to reduce escapement of fish from the sample area. Using an electrofisher adjusted for maximum efficiency, the sample reach is covered thoroughly and all fish discovered are captured and placed in buckets for later enumeration. This process is repeated two more times. At the end of the sampling, each pass is enumerated by species and size in order to develop an estimate of the total number of fish within the sampled area using procedures described in Zippin (1956). It is recommended that three passes be used to improve accuracy.

## ASSUMPTIONS

The assumptions that underlie the method are:

- o The population is essentially stationary;
- o The probability of capture during a trapping is the same for each animal exposed to capture;
- o The probability of capture remains constant from trapping to trapping.

## EFFICIENCY

Although we know that the electrofisher does not catch all of the fish in the sample reach, we assume that the regression reflects the true abundance within the sample reach and that none of the fish were able to escape during sampling.

Turbidity and flow are the dominant factors affecting electrofishing efficiency. Turbid water makes it more difficult to detect and capture fish responding to the electric charge. On the other hand, turbid water is often more conductive and may improve catching efficiency. High flows make it easier for fish to avoid the electric field and to escape downstream.

## FISH HANDLING

Sampled fish should be identified as to species, measured for fork length, and weighed. Fish may be anaesthetized using MS 222 or carbon dioxide.

## ESTIMATING TOTAL STREAM REACH POPULATION

### *Zippin (1956)*

Estimating total juvenile population utilizes the following mark recapture formula:

T= Total catch = $\Sigma y_i = y_1 + y_2 + y_3$
where $y_i$ is the number of fish captured on the $i^{th}$ pass.

$\Sigma(I\text{-}1)y_i = (1\text{-}1)y_1 + (2 - 1)y_2 + (3\text{-}1)y_3$
$= y_2 + 2y_3$

Ratio = $R = y_2 + 2y_3 / T$

To obtain the estimated probability of capture during a single capture, one can utilize Zippin's first graph in Figure 2 for three passes or one can use the formula

$R = (q/1\text{-}q) - kq^3/1 - q^3$

N = total population = total catch/estimated proportion of population captured = $T/(1 - q^3)$

The formula for the standard error of the population estimate N is approximately

$$SE(N) = \left[ \frac{N(N - T)T}{T^2 - N(N - T)\frac{(kp)^2}{(1 - p)}} \right]^{1/2}$$

# METHOD FOR ESTIMATING INSTREAM JUVENILE SALMONID ABUNDANCE USING SNORKELING

**Protocol taken from:** ***Rodgers (2002) and Thurow (1994)***

## PURPOSE

Estimating the density of juvenile salmonids at the project allows the investigator to obtain a sample over time of the change in abundance of rearing juvenile salmonids produced in the stream reach examined. Instead of a randomly selected stream reach, the stream reach impacted by the project is sampled. These “impact” areas have been matched with “control” areas of the same length and size on the same stream whenever possible in order to produce a BACI experimental design.

## EQUIPMENT

Persons conducting snorkel counts should be equipped with dry suits or wet suits, masks, snorkels, and rubber soled boots. Additional equipment such as hand counters and underwater white boards are helpful for enumerating fish.

## SITE SELECTION

The sample reaches are those laid out on page 12.

Be sure that all collectors’ permits and ESA clearances have been obtained before proceeding with electrofishing.

## SAMPLING DURATION

Sampling for juvenile abundance should occur during the low flow period in late summer. It should be done in one or two days within the same week to avoid changes in conditions, rainfall events, etc.

## SAMPLING PROCEDURE

**Step 1:** Begin at the downstream boundary of the control or impact study reach as laid out on page 12 and proceed upstream through the pools and riffles. In many smaller streams the riffle areas will be too shallow to snorkel and will contain mostly smaller young of the year trout species.

**Step 2:** A two person snorkeling crew can conduct snorkel surveys in wadeable stream control and impact study reaches. In areas where the stream is not wadeable, up to four snorkelers may be needed. In wadeable stream reaches, one crew member should snorkel each pool-riffle area while the other crew member records the counts as they are given by the snorkeler. In non-wadeable areas, crew members should snorkel side by side and sum their individual counts. Each snorkeler counts the fish to the immediate front and to the sides opposite the other snorkeler or as designated by the team leader to avoid duplication of counts.

**Step 3**: In all wadeable and most non-wadeable stream reaches, snorkeling should involve only a single pass through each pool-riffle area.

**Step 4**: Counts of the number of juvenile salmonids should be recorded for each pool-riffle area. Summer estimates of juvenile salmonids should be limited to age 1+ fish for all species except chinook salmon (>50mm).

**Step 5**: After snorkeling, the underwater visibility of each study reach is ranked on a scale of 0 to 3 where 0 = not snorkelable due to an extremely high amount of hiding cover or zero water visibility; 1 = high amount of hiding cover or poor water clarity; 2 = moderate amount of hiding cover or moderate water clarity neither of which were thought to impede accurate fish counts; and 3 = little hiding cover and good water clarity.

**Step 6**: Only pool-riffles with a visibility rank of two or three should be used in data analysis. The proportion of trout > 90 mm estimated by sample electrofishing that were cutthroat and steelhead should be used to reclassify unknown trout as underwater determination of species is often impossible.

**Step 7**: Determine area for each pool-riffle utilized in Steps 1-6 by using the methods for determining stream morphology on page 17.

**Step 8:** For each study reach, the number of fish/m2 of pool-riffle habitat can be calculated for chinook, coho, steelhead, and cutthroat by averaging the density estimates for each pool-riffle. A study reach density was obtained for each species of interest by averaging the individual pool-riffle densities.

**Step 9**: Consult Thurow (1994) for additional information.

# TESTING FOR SIGNIFICANCE

We can create a table resembling Table 6 from the connectivity data collected for each of the projects. We can create a table resembling Table 7 for riparian cover, Thalweg Profile, and juvenile and adult abundance.

**Table 6. Example table for testing presence of channel connectivity.**

| | Year 0<br>2003 | Year 1<br>2004 | Year 2<br>2005 | Year 5<br>2008 |
|---|---|---|---|---|
| | **Impact** | **Impact** | **Impact** | **Impact** |
| Proj. 1 | **No** | **Yes** | **Yes** | **Yes** |
| Proj. 2 | **No** | **Yes** | **Yes** | **Yes** |
| Proj. 3 | **No** | **Yes** | **Yes** | **Yes** |
| Proj. 4 | **No** | **Yes** | No | No |
| Proj. 5 | **No** | **Yes** | **Yes** | **Yes** |
| Proj 6 | **No** | **Yes** | **Yes** | **Yes** |
| Proj 7 | **No** | **Yes** | **No** | **No** |
| Proj 8 | **No** | **Yes** | **Yes** | **Yes** |
| Proj 9 | **No** | **Yes** | **Yes** | **Yes** |
| Proj 10 | **No** | **Yes** | **Yes** | **Yes** |
| **Total** | **0** | **10** | **8** | **8** |
| **% Change** | **0** | **100** | **80** | **80** |

**Table 7. Example table for testing BACI differences.**

| | Year 0 | | | Year 1 | | | Year 3 | | | Year 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Treat** | **Cntrl** | **Diff** | **Treat** | **Cntrl** | **Diff** | **Treat** | **Cntrl** | **Diff** | **Treat** | **Cntrl** | **Diff** |
| Proj. 1 | | | | | | | | | | | | |
| Proj. 2 | | | | | | | | | | | | |
| Proj. 3 | | | | | | | | | | | | |
| Proj. 4 | | | | | | | | | | | | |
| Proj. 5 | | | | | | | | | | | | |
| Proj 6 | | | | | | | | | | | | |
| Proj 7 | | | | | | | | | | | | |
| Proj 8 | | | | | | | | | | | | |
| Proj 9 | | | | | | | | | | | | |
| Proj 10 | | | | | | | | | | | | |
| **Mean** | | | | | | | | | | | | |
| **Var.** | | | | | | | | | | | | |

## STATISTICAL TESTING FOR CHANGES IN THE THALWEG PROFILE

Among all of the measures taken in a Thalweg Profile, two measures demonstrate the greatest precision and signal to noise ratio. These are the mean residual Thalweg depth and the residual pool vertical profile area (see Table 8). We wish to test whether the mean residual pool vertical profile area (the cross-sectional area of water that would be contained in pools if no water were flowing) has increased significantly post impact.

The data will be tested using a paired *t*-test. The paired *t*-test is a very powerful test for detecting change because it eliminates the variability associated with individual sites by comparing each stream to itself, that is, at upstream and downstream locations within the same stream. The impact reach and control reach for each stream are affected by the same local environmental factors and local characteristics in the size and depth of pools and riffles in contrast with other stream systems with their own unique environmental conditions. In other words, the two observations of the pair are related to each other.

Because the paired *t*-test is such a powerful test for detecting differences, very small differences may be statistically significant but not biologically meaningful. For this reason, biological significance will be defined as a 20% increase in mean residual depth and residual pool profile area at the impact sites. The statistical test will be one-sided for an Alpha=0.10. We use a one-sided test because a significant decrease in pool area or depth after the impact would not be considered significant, that is, the project would not be considered effective. Therefore, we are not interested in testing for that outcome. The test will be conducted in Years 1, 2, 3, and 5. If the results are significant in any of those years, the instream structure projects will be considered effective.

Our conclusions are, therefore, based upon the differences of the paired scores for the 10 sampled channel connectivity projects. Though somewhat confusing, it may be helpful to think of the statistic as the “difference of the differences”. A one-tailed paired-sample *t*-test would test the hypothesis:

$H_0$ : The mean difference is less than or equal to zero.
$H_A$ : The mean difference is greater than zero.

The test statistic is calculated as:

$$t_{n-1} = \frac{đ - 0}{S_{đ}}$$

where
$\underline{đ}$ = mean of the differences for Year 0 and a subsequent year

$S_{đ}$ = variance of the differences

$S_{đ} = S_d / n^{1/2}$ = variance mean

n = number of sites (or site pairs).

**Table 8. Composite Thalweg variables exhibiting the best all around precision and signal to noise ratios.** RMSE = $\sigma_{rep}$ is the root mean square error. The lower the value, the more precise the measurement. CV $\sigma_{rep}$ / ”(%) is the coefficient of variation. The lower the number, the more precise the measurement. S/N = $\sigma^2_{st(yr)} / \sigma^2_{rep}$ is the signal to noise ratio. The higher the number, the more that metric is able to discern trends or changes in habitat in a single or multiple sites (Kauffman et al., in press, 1999). This table is provided for information purposes only.

| Variable | Description | RMSE = $\sigma_{rep}$ | CV = $\sigma_{rep}$ / ”(%) | S/N = $\sigma^2_{st(yr)}$ / $\sigma^2_{rep}$ |
|---|---|---|---|---|
| AREASUM | Residual Pool vertical Profile Area ($m^2$/reach | 7.6 | 25 | 17 |
| RP100 | Mean residual depth for 100 data points $m^2$/100 m =cm | 2.2 | 19 | 9 |

## TESTING FOR SIGNIFICANCE IN RIPARIAN VEGETATION

Among the measures taken in the riparian area, two measures demonstrate the greatest precision and signal to noise ratio. These are the mean percent canopy shading as measured with a densitometer and the 3 level vegetative canopy layer (see Table 9). We wish to test whether these measures have increased significantly post impact.

The data will be tested using a paired *t*-test as described above. It will test whether there is a change greater than 20% in the calculated difference in the abundance estimate for the impact column and the control column for the sampled projects. This test will be conducted in Years 1, 2, and 5. If the results are significant at Alpha =0.10 in any of those years, the channel connectivity projects will be considered effective.

**Table 9. Composite variable exhibiting the best all-around precision and signal to noise ratios.** RMSE = $\sigma_{rep}$ is the root mean square error. The lower the value, the more precise the measurement. CV $\sigma_{rep}$ / ”(%) is the coefficient of variation. The lower the number, the more precise the measurement. S/N = $\sigma^2_{st(yr)} / \sigma^2_{rep}$ is the signal to noise ratio. The higher the number, the more that metric is able to discern trends or changes in habitat in a single or multiple sites. This table is provided for information purposes only.

| Variable | Description | RMSE = $\sigma_{rep}$ | CV = $\sigma_{rep}$ / ”(%) | S/N = $\sigma^2_{st(yr)}$ / $\sigma^2_{rep}$ |
|---|---|---|---|---|
| XCDENBK | Mean % canopy density at bank (Densitometer reading) | 3.9 | 4.4 | 17 |
| XC DENMID | Mean % canopy density midstream (Densitometer reading) | 5.8 | 8.1 | 15 |
| XCM | Mean riparian canopy + mean mid layer cover | 0.22 | 33 | 1.4 |
| XPCM | Riparian canopy and mid layer presence (proportion of reach) | 0.08 | 9.8 | 7.9 |
| XPCMG | 3-layer riparian vegetation presence (proportion of reach) | 0.08 | 9.8 | 8.0 |

## TESTING FOR SIGNIFICANT CHANGES IN JUVENILE ABUNDANCE

We wish to test if juvenile salmon abundance in terms of numbers per square meter, has increased significantly post impact. The annual variation in numbers is significant as can be seen in Table 10 taken from Bisson et al. (in press).

The number of juveniles per square meter has been shown to be more descriptive than using either linear measures (#/m) or volume measures (#/$m^3$).

The data will be tested using a paired *t*-test as described above. It will test whether there is a change greater than 20% in the calculated difference in the abundance estimate for the impact column and the control column for the sampled projects. This test will be conducted in Years 1, 2, and 5. If the results are significant at Alpha =0.10 in any of those years, the channel connectivity projects will be considered effective.

**Table 10. Average coefficient of variation of the inter-annual abundance of adults and juvenile salmonids.** Data source Bisson et al. An asterisk denotes a significant difference (P < 0.10, single classification ANOVA) in comparison with other life stages of that species. The number of populations is shown in parentheses. This table is provided for information purposes only.

| Species | Adult | Juvenile | Smolt |
|---|---|---|---|
| | | | |
| Steelhead | 60 (3) | 66 (6) | 50 (5) |
| Coho | 72* (21) | 53 (25) | 50 (11) |
| Cutthroat | 92 (1) | 54 (6) | 64 (3) |

# DATA MANAGEMENT PROCEDURES

Data will be collected in the field using various hand-held data entry devices. Raw data will be kept on file by the project monitoring entity. A copy of all raw data will be provided to the SRFB at the end of the project. Summarized data from the project will be entered into the PRISM database after each sampling season. The PRISM database contains data fields for the following parameters associated with these objectives.

**Table 11. PRISM data requirements for instream artificial structure habitat projects.**

| Indicator | Metric | Pre impact Year 0 | Post impact Year 1 | Post impact Year 2 | Post impact Year 5 |
|---|---|---|---|---|---|
| Side Channel distance | miles | √ | | | |
| Side Channel area | acres | √ | √ | √ | √ |
| Side Channel wetted area | acres | √ | √ | √ | √ |
| Level 1 effective | Yes/No | | √ | √ | √ |
| Riparian Canopy Covers impact | Mean % canopy density at the bank | √ | √ | √ | √ |
| Riparian Canopy Covers control | Mean % canopy density at the bank | √ | √ | √ | √ |
| Statistically significant | Yes/No | | | √ | √ |
| Riparian Cover impact | Mean proportion of impact reaches where 3 vegetation layers are present | √ | √ | √ | √ |
| Riparian Cover control | Mean proportion of control reaches where 3 vegetation layers are present | √ | √ | √ | √ |
| Thalweg Profile Impact AREASUM | % change in residual pool profile area m2 | √ | √ | √ | √ |
| Thalweg profile Impact RP100 | Mean residual depth cm | √ | √ | √ | √ |
| Thalweg Profile Control AREASUM | % change in residual pool profile area m2 | √ | √ | √ | √ |
| Thalweg profile Impact RP100 | Mean residual depth cm | √ | √ | √ | √ |
| Level 2 effective | Yes/No | | √ | √ | √ |

| Indicator | Metric | Pre impact Year 0 | Post impact Year 1 | Post impact Year 2 | Post impact Year 5 |
|---|---|---|---|---|---|
| Juvenile salmon abundance summer Impact | #/m$^2$ | √ | √ | √ | √ |
| Juvenile salmon abundance summer control | #/m$^2$ | √ | √ | √ | √ |
| Juvenile salmon abundance winter impact | #/m$^2$ | √ | √ | √ | √ |
| Juvenile salmon abundance winter control | #/m$^2$ | √ | √ | √ | √ |
| Level 3 effective | Yes/No | | √ | √ | √ |

# REPORTS

## PROGRESS REPORT

A progress report will be presented to the SRFB in writing after the sampling season for Years 1 and 5.

## FINAL REPORT

A final report will be presented to the SRFB in writing after the sampling season for Year 10. It shall include:

- Estimates of precision and variance.
- Confidence limits for data.
- Summarized data required for PRISM database.
- Determination whether project met decision criteria for effectiveness.
- Analysis of completeness of data, sources of bias.

Results will be reported to the SRFB during a regular meeting after 1, 5, and 10 years post project. Results will be entered in the PRISM database and will be reported and available at the Interagency Committee for Outdoor Recreation website and the Natural Resources Data Portal.

# ESTIMATED COST

It is estimated that approximately 80 hours per project would be required to conduct all field activities under the protocol. This results in a relative 2004 cost of $6,000 per project.

# REFERENCES CITED

Bisson, P.A., S.V. Gregory, T.E. Nickelson, and J.D. Hall. IN PRESS. The Alsea Watershed Study: A Comparison with other multi-year investigations in the Pacific Northwest. J. Stednick and J.D. Hall (editors), The Alsea Watershed: Hydrological and Biological Responses to Temperate Coniferous Forest Practices. Springer-Verlag, New York.

Crawford, B.A., C. Drivdahl, S. Leider, C. Richmond, and S. Butkus (2002). The Washington Comprehensive Monitoring Strategy for Watershed Health and Salmon Recovery. Vol. 2. Olympia, WA. 377p.

Hankins, D.G. (1984). Multistage sampling design in fisheries research: Applications in small streams. Can. J. Fish. Aquat. Sci. 41: 1575-1591.

Hankins, D.G. and G.H. Reeves (1988). Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Can. J. Fish. Aquat. Sci. 45: 834-844.

Kauffman, P.R., P. Levine, E.G. Robinson, C. Seeliger, and D.V. Peck (1999). Quantifying physical habitat in wadeable streams. EPA/620/R-99/003. U.S. Environmental Protection Agency, Washington, D.C.

Mebane, C., T.R. Maret, R.M. Hughes (2003). An index of biological integrity (IBI) for Pacific Northwest rivers. Trans. Amer. Fish. Soc. 132:239-261.

Peck, D.V., J.M. Lazorchak, and D.J. Klemm (editors). Unpublished draft. Environmental Monitoring and Assessment Program -Surface Waters: Western Pilot Study Field Operations Manual for Wadeable Streams. EPA/XXX/X-XX/XXXX. U.S. Environmental Protection Agency, Washington, D.C.

Rodgers, J.D. (2002). Abundance monitoring of juvenile salmonids in Oregon coastal streams, 2001. Mon. Rpt. No. OPSW-ODFW-2002-1. Oregon Dept. Fish and Wildlife. Portland, OR. 51p.

Salmon Recovery Funding Board (2003). Sampling protocols; Effectiveness monitoring requirements. Interagency Committee for Outdoor Recreation. Olympia, WA. 41p.

Stewart-Oaten, A., W.W. Murdoch, and K.R. Parker (1986). Ecology. Vol. 67(4) pp. 929-940.

Thurow, R.F. (1994). Underwater methods for study of salmonids in the Intermountain West. U.S. Forest Service. Gen Tech Rept. INT-GTR-307. 29 p.

Underwood, A.J. (1994). On beyond BACI: Sampling designs that might reliably detect environmental disturbances. Ecological Applications. 4(1):pp 3-15.

Zippin, C. (1956). The removal method of population estimation. Journal of Wildlife Management 22:82-90.